High Workability, High Durability Concre… Middle East – A Ca…

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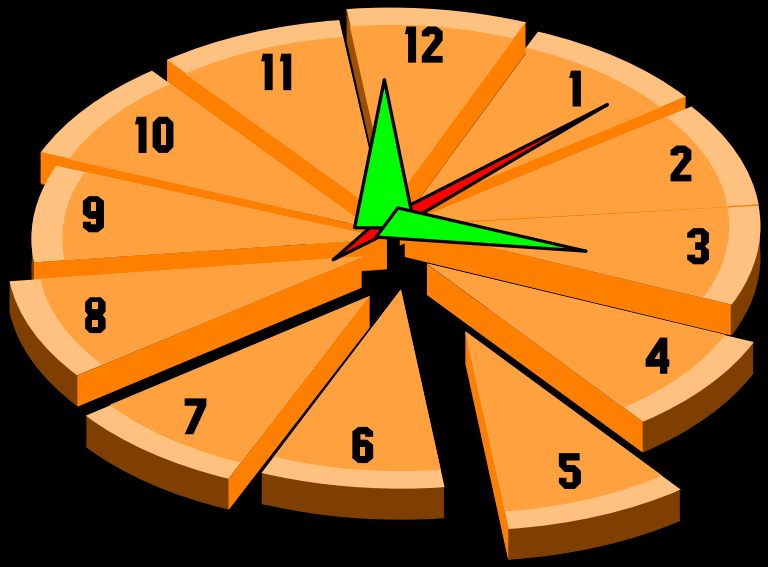
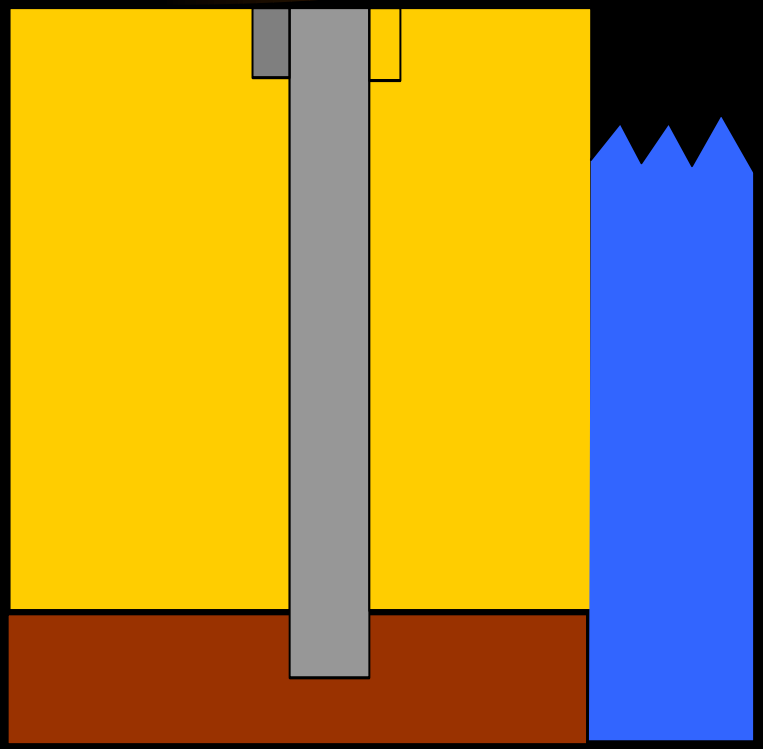
Agenda

- Project Background
- Problems with D-wall construction
- Employers Requirements
- Contractors Proposal
- Results
- Construction



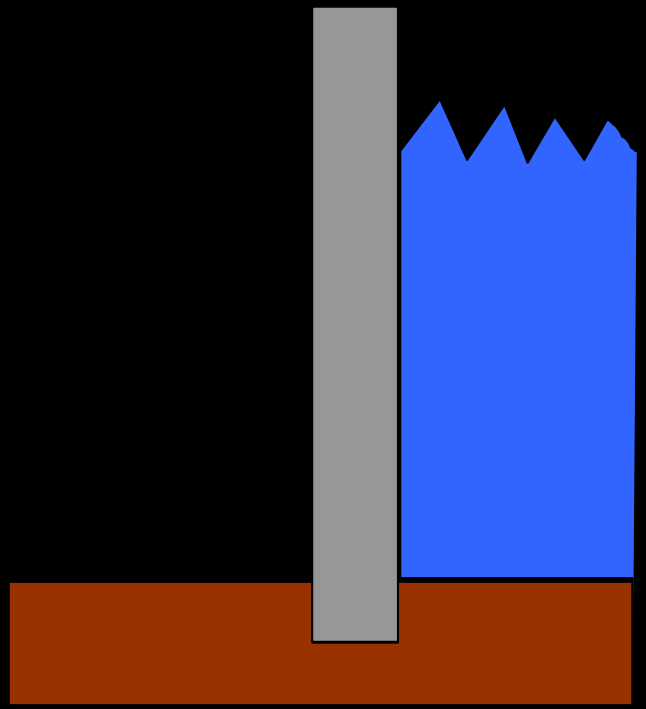
Project Background

- Reclaimed land (sand fill)
- Edge protection
- Cast D-Wall



Project Background

- Excavation of fill to form new sea wall
- Removal of edge protection
- Many kilometers of sea wall required



Problems with D-Wall Construction

- Bentonite inclusions
- Bleed under pressure (voids beneath steel)
- Placement below concrete surface
- Continuous placement
- 3 hour slump retention
- Spacer block retention

Problems with D-Wall Construction

Employer's Requirements

- Minimum cube strength 45MPa
- Min cementitious content 380 kg/m^3
- Max. cementitious content 450 kg/m^3
- Max. w/c ratio 0.38
- Max. crack width 0.1mm
- 75mm concrete cover
- Max. chloride 0.2% mass of cement
- ASR – non reactive aggregate
- No spalling in 100 years
- Required cementitious mix content (option A or B)

Employer's Requirements

Option A

- 50 – 70% ordinary or rapid hardening portland cement
- 25 – 40% pulverised fuel ash
- 5 – 10% condensed silica fume

Option B

- 15 – 35% ordinary or rapid hardening portland cement
- 60 – 75% ground granulated blast furnace slag
- 5 – 10% condensed silica fume

Contractor's Proposal

- 650kg 20mm crushed aggregate
- 310kg 10mm crushed aggregate
- 540kg crushed sand
- 350kg dune sand
- 126kg OPC
- 294kg GGBFS
- 155kg free water
- Free w/c ratio 0.37
- 7.2 litres super plasticiser (high end water reducer)
- 0.4 litres of plasticiser
- Designed slump 200mm

Contractor's Justification

- CSF Removed due to anticipated problems with workability resulting from small particle size of CSF (2 microns) and expected increased setting times
- Increase cover from 75mm to 95mm and design crack width up to 0.15mm from 0.1mm
- Durability of mix justified using LIFE 365 (freely available durability modeling software) which demonstrated that with 95mm cover and 0.15mm crack width chlorides would not reach the reinforcement within 100 years (required no spalling period)

Durability

- ISAT
- Permeability
- Cover
- W/c Ratio
- Chloride Ingress
- Temperature Control
- Alkali Silica Reactivity (ASR)

ISAT (initial surface absorption)

- GGBFS concrete ISAT results more variable than plain OPC concrete.
- Similar overall values between concrete with and without GGBFS
- Short term performance (e.g. 28 days) non-GGBFS lower but similar results achieved at 1 year.
- Affected by surface condition of the concrete so may deteriorate over time

Permeability

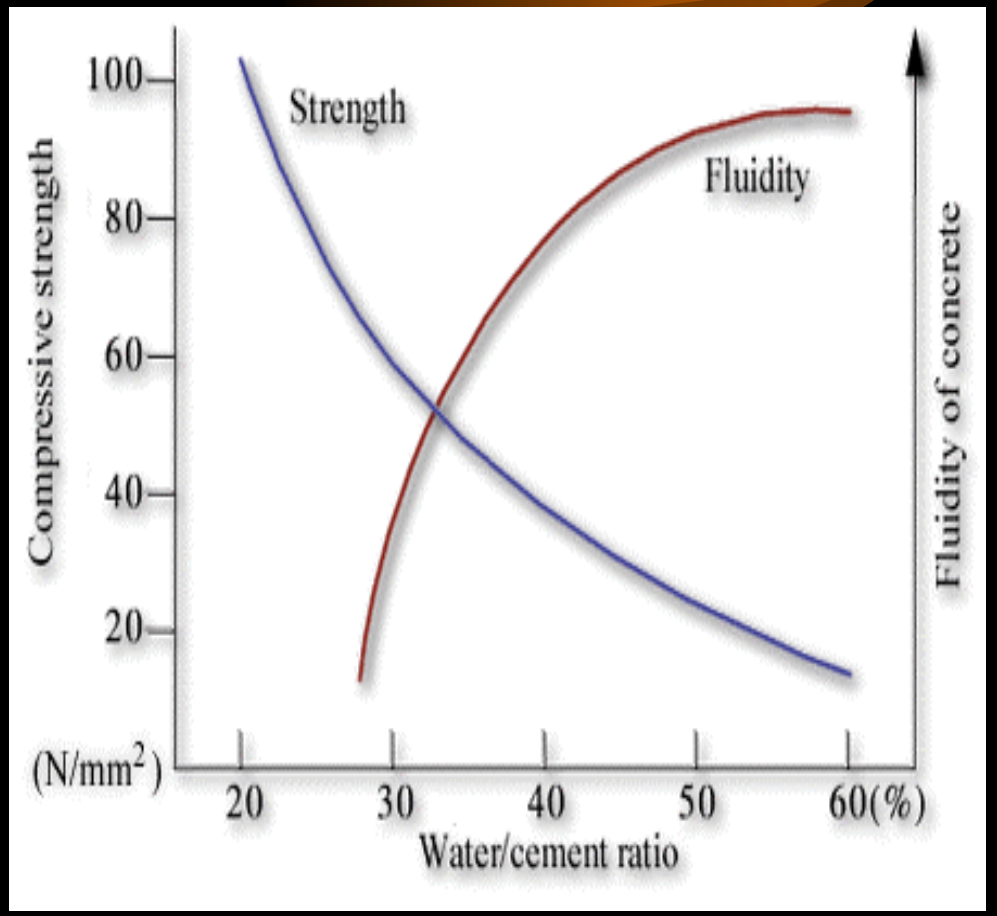
- Permeability reduced as strength increased.
- Durability largely controlled by rate at which water, oxygen, CO2, etc. can move through the hardened concrete.
- Low w/c ratio and inclusion of GGBFS reduced permeability

Cover

- 95mm cover from outermost bars
- Spacer blocks manufactured for the project from same concrete
- Proper fixing and placement of cage

Water to Cementitious Ratio

- Significant effects on workability, low w/c needs to be compensated by additives, aggregate grading and selection to maintain workability
- Significant effect on durability
- Low w/c increases strength and reduces permeability
- Reduced bleed



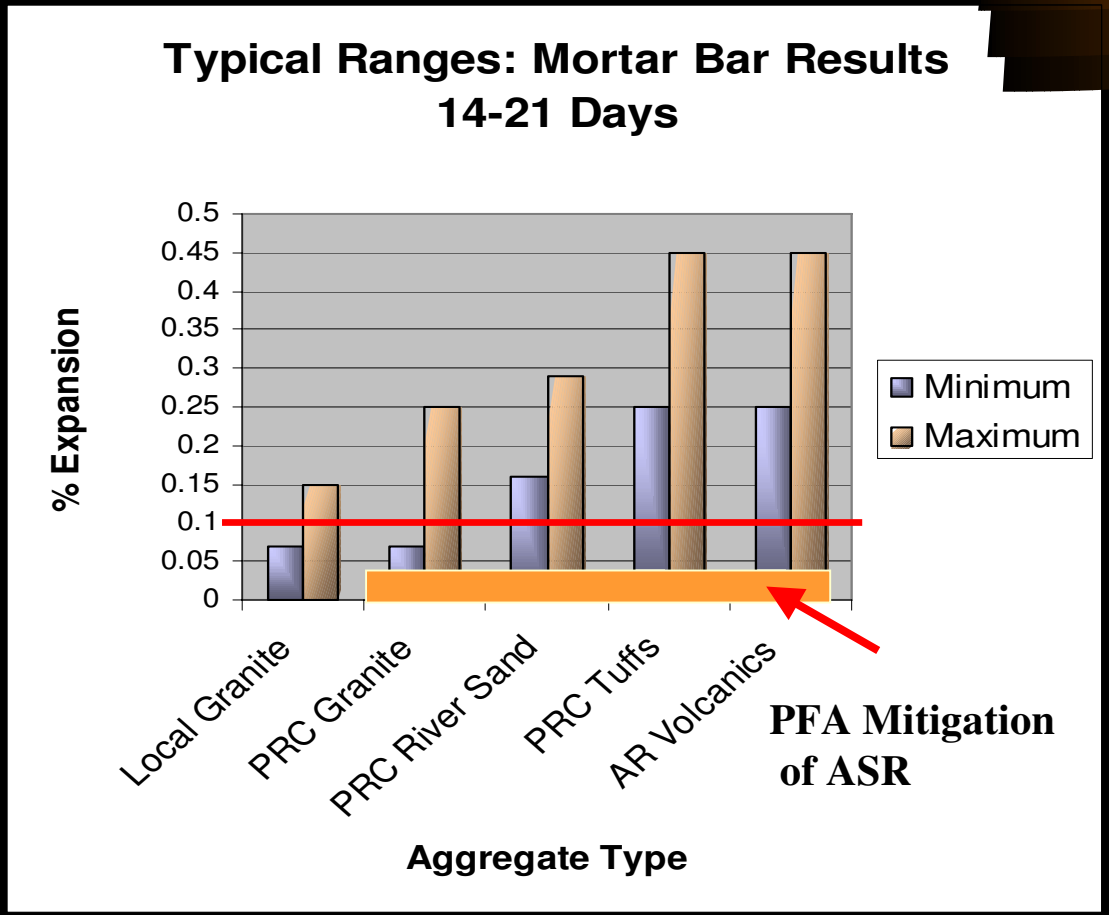
Chloride Ingress

- Likely to be most significant deterioration mechanism
- Accelerated chloride penetration in NaCl solution lower after 56 days compared to 28
- ASTM C1202 rapid indication of chloride resistance

Temperature Control

- Early age thermal effect induced cracking
- Placement temperature 32^{o}C, max temp. 65^{o}C
- GGBFS reduce temperature rise and early age strength
- Use of crushed ice as 65% of free water

ASR Mitigation



ASR Mitigation

- Aggregate selected to be non reactive and tested by mortar bars in accordance with Canadian Standard A23.2-25A.
- Use of GGBFS in mixture provides reserve protection from reactive aggregates due to reduced alkali content

Workability trials

- Slump over 250mm
- Slump retention over 3 hours
- Slump flow (non standard)

Concrete Cubes

- 14 day strength over 47 MPa
- Charge passed 834 coulombs at 7 days ASTM C1202

Trial Results

- High concrete strength significantly in excess of minimum 45MPa at 28 days in order to achieve durability requirements
- High slump with acceptably low water to cementitious ratio
- Acceptable slump retention to give retained concrete workability to end of pour (first poured material being pushed up by later material)
- 834 coulombs passed (i.e. very low chloride ion permeability)
- Proposed mix accepted by employer

Site Conditions

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Conclusion

- Workability and durability need to be considered together. If the most durable laboratory mix isn't workable the final constructed product is unlikely to achieve durability expectations.
- Environmentally friendly solution – use waste products to improve concrete durability
- Provisions for future cathodic protection – Remedial measure or part of the design solution?

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